PETROGRAPHIC STUDIES AND $^{40}Ar/^{39}Ar$ DATING OF TWO GREEN RIVER FORMATION TUFFS FROM THE SOUTHERN GUNNISON PLATEAU AREA, UTAH

Senior Thesis

By

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TABLE OF CONTENTS

FIGURES

TABLES

ABSTRACT

Petrographic, $^{40}Ar/^{39}Ar$ dating, and stratigraphic data are all implemented in attempting to show the relationship between two tuffs from the Green River Formation in the Southern Gunnison Plateau area and, to determine if the two tuffs are of a common origin. Tuffs LN-1 and G-33 were collected at outcrops 9.66 kilometers apart. The petrographic studies show the tuffs are composed of similar minerals in similar proportions. $^{40}Ar/^{39}Ar$ dating shows the age of tuff LN-1 is 45.1 ± 0.4 m.y., and tuff G-33 has an age of 45.6 ± 0.4 m.y. The tuffs at both localities are underlain and overlain by identical units of green mudstone and gray limestone respectively. Also, both tuff beds are 25 cm thick. These tuffs may be identical to the tuff (RLM-6-71) studied by Mauger (1977). A common volcanic origin for the tuffs is probable.

INTRODUCTION

This thesis is an attempt to determine whether two tuffs from different localities in the Green River Formation were derived from the same volcanic event. The criteria for determining the relationship is based on petrographic studies, $^{40}Ar/^{39}Ar$ dating, and stratigraphy within the Green River Formation. In the petrographic studies, the mineral compositions and the percentage of each mineral in the tuffs are compared. Age comparisons are made by dating the biotite grains in the tuffs. After assessing this information, the plausibility of the opening hypothesis will be discussed.

Both tuffs were collected by William Schreiner, a graduate student (M.S.) at Ohio State University, during the summer of 1980. Schreiner is studying lacustrine deposition of the Green River Formation (Eocene) in western Sevier, Sanpete, and southeastern Juab counties in Utah. A detailed sedimentological analysis will be made by studying carbonate petrology, depositional features, structure, and isotopic dating (using the K/Ar and $^{40}Ar/^{39}Ar$ techniques) of tuff beds within the formation. This information will be used to correlate the Green River Formation in this field area with the Green River units on the southeastern portion of the paleolake studied by

Sheliga (1980) and the Green River rocks in the Uinta structural basin.

THE GREEN RIVER FORMATION

The Green River Formation is found throughout northwestern Colorado, southwestern Wyoming, northeastern Utah, and central Utah. It was named by Hayden (1869) for outcrops near Green River, Wyoming. Bradely (1931) described the type section in great detail. The formation forms prominent hogbacks in central Utah along the Wasatch monocline in the Sanpete and Sevier valleys and occurs throughout the southern part of the Gunnison Plateau.

In central Utah, the Green River Formation is largely fresh-water limestone and shale. It is dominated by light-gray argillaceous thin-bedded limestone, gray shale, gray dense limestone, and light-gray, coarse-medium grained sandstone. Plant fossils occur in the shales and sandstones.

In the southern part of the area, the upper part of the Green River Formation is marked by a unit of green-gray shale, with a few interbedded layers of limestone, about 250 feet thick. At least 250 feet of light-gray limestone occur above this unit. This sequence is typical of the southern part of the Gunnison Plateau and of the Wasatch Plateau.

The lower contact of the Green River Formation is conformable with the Colton Formation. The two formations do intertongue somewhat. In areas where the Colton Formation is not differentiated, the Green River Formation appears to be conformable with the Flagstaff limestone.

Bradely (1931) considers the Green River Formation in Wyoming and northeastern Utah as Middle Eocene. In all probability, the Green River Formation in central Utah is of the same age, because the fossils found there do not differ from those described by Bradely (A. La Rocque, personal communication). Therefore, the Green River Formation in this area is considered Middle Eocene. This background information is from Hardy and Zellar (1953).

LOCATION OF THE TUFFS

Both tuffs are from the southern Gunnison Plateau area and are designated LN-1 and G-33. They were collected at outcrops 9.66 kilometers apart.

The location for sample LN-1 is SE$\frac{1}{4}$, SW$\frac{1}{4}$ quadrant, section 14, T. 19 S., R. 1 E. It is 4.02 kilometers east from the southern limits of the town of Gunnison, Utah.

Sample G-33 is located SW$\frac{1}{4}$, SW$\frac{1}{4}$ quadrant, section 13, T. 18 S., R. 1 E.

The locations for both samples comes from the topographic map: " Gunnison Quadrangle, Utah - Sanpete Co., 7.5 minute series (Topographic), N. 3907.5 - W. 11145/ 7.5, 1966, AMS 3662 III - Series V 897."

Both tuffs were collected in fairly similar horizons in the Green River Formation.

The section where sample LN-1 was collected is 10 meters of green mudstone overlain by 25 cm. of tuff LN-1. This tuff is overlain by 20 cm. of gray limestone.

The section where sample G-33 was collected includes 4.5 meters of green mudstone which is overlain by 60 cm. of finely laminated mudstone and 90 cm. of green mudstone. This is overlain by 25 cm. of tuff G-33. Above the tuff is a 20 cm. unit of gray limestone.

Siliceous rich limestone ledges lie above the limestone units in both sections.

PETROGRAPHIC STUDIES

The two tuffs were studied microscopically with four thin-sections for each sample. Analysis was determined by studying the mineral content, percentage of each of the minerals, and their shape.

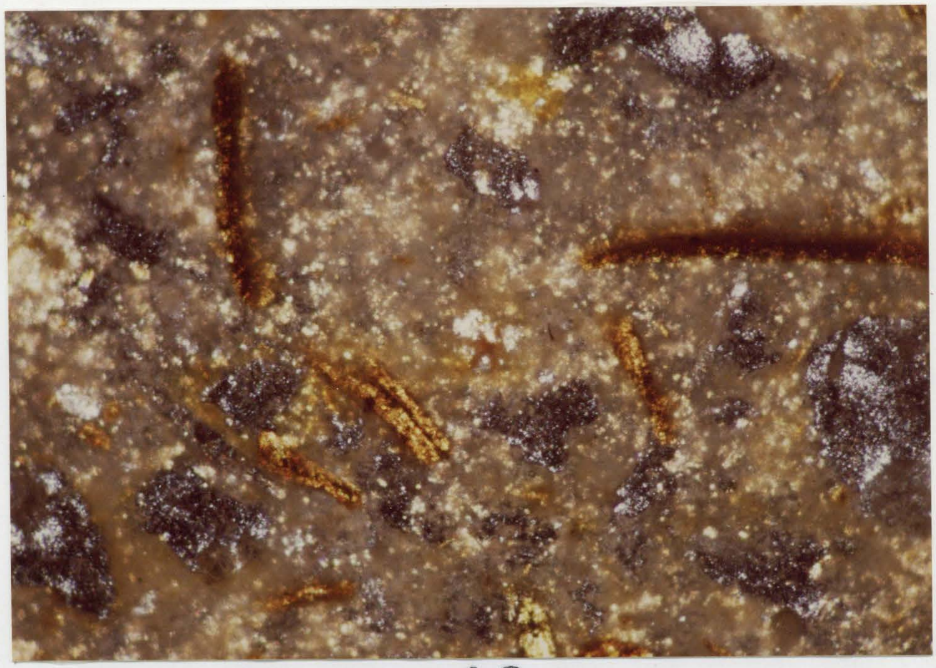
Sample LN-1 is a micaceous tuff. Euhedral biotite grains make-up 12% of the tuff, and euhedral hornblende grains make-up 1% of the tuff. Altered potassium feldspar in the form of sanidine forms 6% of the tuff. These grains are subhedral to euhedral. The matrix is probably illite and composes 80% of the sample. Quartz and iron oxide form less than 1% of the tuff.

Sample G-33 is a micaceous tuff. Euhedral biotite grains compose 11% of the tuff, and euhedral hornblende grains form 5% of the sample. Altered potassium feldspar in the form of sanidine makes-up 10% of the rock. These grains are subhedral to euhedral. The matrix is probably illite and composes 73% of the sample. Quartz and iron oxide form less than 1% of the tuff.

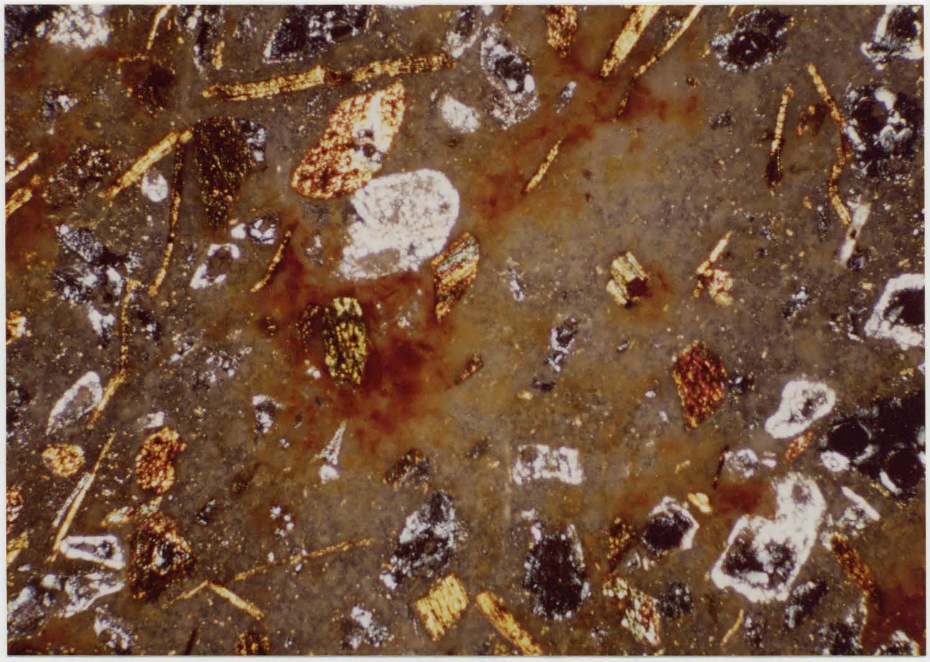
Both samples are composed of the same minerals, but the percentages differ somewhat. Sample G-33 has a higher percentage of hornblende and sanidine, but a lower percentage of matrix. Microphotographs of both samples are shown on the following page: figure 1.

PREPARATION OF THE TUFFS FOR DATING ANALYSIS - see figures 2&3

For $^{40}Ar/^{39}Ar$ dating of these samples, the biotite must be separated to greater than 99% pure. Flowcharts showing the procedure are shown in figures 2&3. The procedures used are

a. 

2 mm 10 x

b. 

2 mm 4 x

Figure 1: a) Microphotograph of sample LN-1

b) Microphotograph of sample G-33

given below.

The grains are first mechanically separated from the tuff. To assure the grains are as fresh as possible, the weathered rind is cut off on a water saw. The sample is then crushed in a jaw crusher and ground on a disc grinder. A representative sample is taken after the crushing and is stored for future reference. The crushed rock is then sieved according to grain size. The 40-60 mesh size for both samples can now be purified.

Heavy liquid separation is the next step in purifying the biotite. First, the samples are washed with water and acetone. Then, the sample is passed through bromoform (density = 2.85) to remove the lighter grains. After drying, the bromoform "heavies" pass through a mixture of 1/3 bromoform and 2/3 methylene iodide. The sample is again dried and passed through methylene iodide to remove the heavy grains.

The sample is examined under a microscope for purity and is then given a final wash with distilled water, acetone, and alcohol. The purified biotite is then dried in an oven and may be prepared for the reactor.

SAMPLE PACKAGE

Two aliquots of each sample were packaged in aluminum

ROCK PROCESSING - FLOW CHART - Figure 2

SAMPLE LN-1

WEATHERED RIND REMOVED

↓

ROCKS CRUSHED → SPLIT FOR REP. SAMPLE

↓

GROUND

↓

SIEVED ACCORDING TO GRAIN SIZE (MESH SIZES)

(>40) (40-60) (60-80) (80-100) (<100)

↓

WASHED WITH DISTILLED WATER AND ACETONE

↓

HEAVY LIQUID SEPARATION (BROMOFORM)

B(H) B(L) - TWO BOTTLES

↓

1/3 BROMOFORM 2/3 M.I.

1/3 B(H) 1/3 B(L) - ONE BOTTLE

M.I. (L) M.I. (H)

↓

PAPER SHAKING

UNPURE BIOTITE PURE BIOTITE

↓

FINAL WASH

↓

ACETONE

↓

ALCOHOL

↓

DISTILLED WATER (THREE TIMES)

ROCK PROCESSING - FLOW CHART - Figure 3

SAMPLE G-33

WEATHERED RIND REMOVED

↓

ROCKS CRUSHED → SPLIT FOR REP. SAMPLE

↓

GROUND

↓

SIEVED ACCORDING TO GRAIN SIZE (MESH SIZES)

(>40) (40-60) (60-80) (80-100) (<100)

↓

WASHED WITH DISTILLED WATER AND ACETONE

↓

HEAVY LIQUID SEPARATION (BROMOFORM)

B(H) B(L) - TWO BOTTLES

↓

1/3 BROMOFORM 2/3 M.I.

1/3 B(H) 1/3 B(L) - ONE BOTTLE

M.I. (L) M.I. (H)

↓

PAPER SHAKING

UNPURE BIOTITE PURE BIOTITE (HORNBLENDE PRESENT)

↓

FINAL WASH

↓

ACETONE

↓

ALCOHOL

↓

DISTILLED WATER (THREE TIMES)

capsules. The capsules were then sealed in silica glass vials. These vials were included in the OSU-MICH #24, $^{40}Ar/^{39}Ar$ irradiation package.

The package was irradiated for 80 hours in the H-5 facility of the reactor at the Phoenix Memorial Laboratory at the University of Michigan receiving a total neutron dose of about 1 x 10^{18} neutrons. The details of the package are in table 1.

Table 1

SAMPLE	CAPSULE #	WEIGHT OF BIOTITE	GEOMETRY NOTATION
G-33	68	0.25149 grams	0-10
G-33	69	0.27862 grams	10-20
LN-1	70	0.28180 grams	20-30
LN-1	71	0.27475 grams	30-38

$^{40}Ar/^{39}Ar$ DATING

Both biotite samples were dated by the $^{40}Ar/^{39}Ar$ technique. The method, in use since the late 1960's, is described by Dallmeyer (1979) and is a variant of the K-Ar dating technique described in detail by Dalrymple and Lanphere (1969).

The $^{40}Ar/^{39}Ar$ method involves measurement of the $^{40}Ar/^{39}Ar$ ratio following irradiation with fast neutrons to produce

^{39}Ar via the reaction $^{39}K(n,p)^{39}Ar$. With this technique, absolute concentrations of ^{40}Ar and ^{40}K need not be measured since the age is a function of the $^{40}Ar/^{39}Ar$ ratio for a given neutron dose. A particular advantage is that gas may be released incrementally, in a stepwise fashion with increasing temperature, and each gas fraction gives an "age." The age calculated is based upon the measured $^{40}Ar/^{39}Ar$ ratios of monitors of known age which were simultaneously irradiated. The details of the procedure along with the equations are given by Dallmeyer (1979).

In the present study, argon was released in six or seven steps. The sample was heated for 30 minutes at each temperature. Then, the argon was purified by Cu-CuO and Ti gettering before analysis. The procedures are similar to those described by Dalrymple and Lanphere (1969). The argon isotopes were measured with a six-inch, Nier-type gas source spectrometer with on-line data acquisition and reduction by a minicomputer.

Several monitors were run. The ages are relative to an intralaboratory monitor, muscovite #818-79-7, with an age of 66.3 m.y. A sample of the LP-6 biotite interlaboratory standard was used as a check on the muscovite monitor.

Ages were calculated using the presently accepted ^{40}K constants given by Steiger and Jäger (1977). These are: $\lambda(^{40}K_{\beta}-) = 4.962 \times 10^{-10}\ yr^{-1}$; $\lambda(^{40}K_{e}tot) = 0.581 \times 10^{-10}\ yr^{-1}$; $^{40}K = 0.01167$ atom % of K; and, atmosphere air argon with

$^{40}Ar/^{36}Ar = 295.5$.

$^{40}Ar/^{39}Ar$ RESULTS

The results of the $^{40}Ar/^{39}Ar$ analysis are given in Tables 2 through 5 and Figures 4 through 7. The first sample run, #68, G-33 biotite, had relatively large air argon corrections due to insufficient outgassing of the vacuum line. The other samples had atmospheric ^{40}Ar corrections less than 25%.

The ages, obtained by adding all the gas fractions, are 44.1 and 44.3 m.y. for G-33, and 41.5 and 42.0 m.y. for LN-1. The release spectra (Figures 4-7) show marked discordance with low ages for the first gas fraction. Thus, the "total gas" ages cannot be used, and the discordance probably indicates post-crystallization modification or alteration of the biotite. In spite of this discordance, good plateau ages are obtained. The plateau represents ages which are indistinguishable at the 95% confidence level for contiguous gas fractions which constitute more than 50% of the gas (see, Fleck et al, 1977). The plateaus show that most of the sample has a homogeneous $^{40}Ar/K$ ratio. The plateau ages give the most reliable ages for these samples.

The age of the first fraction of sample #68, 36.5 ± 0.7 m.y., is markedly lower than the other fractions. This fraction

Table 2: DATA FOR SAMPLE G-33 BIOTITE (#68 OF OSUMI #24) J=0.006033

TEMP. °C	40/39 MEAS.	36/39 MEAS.	CORRECTED SIGNAL (MILLIVOLTS) ^{40}Ar	^{39}Ar	^{36}Ar	F	39 Ar % OF TOTAL	% RADIOGENIC ^{40}Ar	AGE (m.y.)
650	7.312	0.013244	764.26	104.53	1.3844	3.392	15.89	46.39	36.544 ± 0.656
775	10.615	0.022067	1038.81	97.86	2.1594	4.089	14.88	38.52	43.959 ± 0.855
875	19.805	0.052631	1218.78	61.54	3.2389	4.246	9.36	21.44	45.630 ± 1.387
1010	32.252	0.094856	1659.11	51.44	4.8796	4.216	7.82	13.07	45.313 ± 2.306
1075	10.869	0.022350	3064.69	281.98	6.3021	4.258	42.88	39.18	45.760 ± 0.747
FUSE	30.276	0.087595	1824.85	60.27	5.2796	4.386	9.17	14.49	47.114 ± 1.959
TOTAL GAS	14.553	0.035346	9570.48	657.62	23.2440	4.103	100 %	28.19	44.107

Table 3: DATA FOR SAMPLE G-33 BIOTITE (#69 OF OSUMI #24) J=0.006055

TEMP. °C	40/39 MEAS.	36/39 MEAS.	CORRECTED SIGNAL (MILLIVOLTS) ^{40}Ar	^{39}Ar	^{36}Ar	F	39 Ar % OF TOTAL	% RADIOGENIC ^{40}Ar	AGE (m.y.)
601	5.932	0.011743	281.59	47.47	0.5575	2.456	5.93	41.40	26.626± 0.685
602	5.021	0.003728	267.10	53.20	0.1983	3.913	6.65	77.94	42.247± 0.757
603	4.783	0.001611	1032.45	215.86	0.3477	4.301	26.99	89.93	46.378± 0.529
750	4.623	0.001401	954.04	206.36	0.2892	4.203	25.80	90.91	45.337± 0.512
950	4.645	0.001502	1243.23	267.65	0.4019	4.195	33.46	90.32	45.253± 0.514
1025	12.493	0.027467	74.61	5.97	0.1640	4.370	0.75	34.98	47.118± 4.403
FUSE	25.915	0.070592	87.34	3.37	0.2379	5.049	0.42	19.48	54.324± 6.933
TOTAL GAS	4.926	0.002746	3940.35	799.88	2.1966	4.109	100 %	83.41	44.332

Table 4: DATA FOR SAMPLE LN-1 BIOTITE (#70 OF OSUMI #24) J=0.006050

TEMP. °C	40/39 MEAS.	36/39 MEAS.	CORRECTED SIGNAL (MILLIVOLTS) ^{40}Ar	^{39}Ar	^{36}Ar	F	39 Ar % OF TOTAL	% RADIOGENIC ^{40}Ar	AGE (m.y.)
600	4.529	0.007932	815.36	180.04	1.4282	2.179	17.02	48.11	23.623± 0.409
700	4.982	0.002782	1316.49	264.24	0.7351	4.154	24.98	83.38	44.778± 0.514
800	5.132	0.003134	1068.21	208.13	0.6524	4.200	19.68	81.84	45.268± 0.526
820	4.758	0.001844	967.34	203.32	0.3749	4.207	19.22	88.42	45.340± 0.526
920	5.087	0.002899	282.58	55.55	0.1610	4.225	5.25	83.05	45.530± 0.681
1010	4.475	0.000940	554.41	123.89	0.1164	4.191	11.71	93.66	45.176± 0.512
FUSE	17.204	0.043345	387.63	22.53	0.9766	4.390	2.13	25.52	47.284± 1.971
TOTAL GAS	5.098	0.004202	5392.01	1057.71	4.4446	3.850	100 %	75.53	41.540

Table 5: DATA FOR SAMPLE LN-1 BIOTITE (#71 OF OSUMI #24) J=0.006024

TEMP. °C	40/39 MEAS.	36/39 MEAS.	CORRECTED SIGNAL (MILLIVOLTS) ^{40}Ar	^{39}Ar	^{36}Ar	F	39 Ar % OF TOTAL	% RADIOGENIC ^{40}Ar	AGE (m.y.)
600	4.789	0.004172	1994.16	416.43	1.7372	3.550	44.69	74.13	38.172± 0.448
750	4.952	0.002580	970.37	195.97	0.5055	4.183	21.03	84.49	44.897± 0.511
850	4.835	0.002067	959.06	198.37	0.4100	4.218	21.29	87.24	45.265± 0.507
950	4.599	0.001273	459.51	99.92	0.1272	4.217	10.72	91.69	45.250± 0.531
1025	6.198	0.006831	89.54	14.45	0.0987	4.174	1.55	67.34	44.797± 4.312
1075	14.360	0.033720	46.28	3.22	0.1087	4.390	0.35	30.57	47.084± 5.395
FUSE	40.192	0.122785	140.99	3.51	0.4307	3.903	0.38	9.71	41.923± 6.593
TOTAL GAS	5.001	0.003668	4659.90	931.88	3.4181	3.911	100 %	78.21	42.005

Figure 4

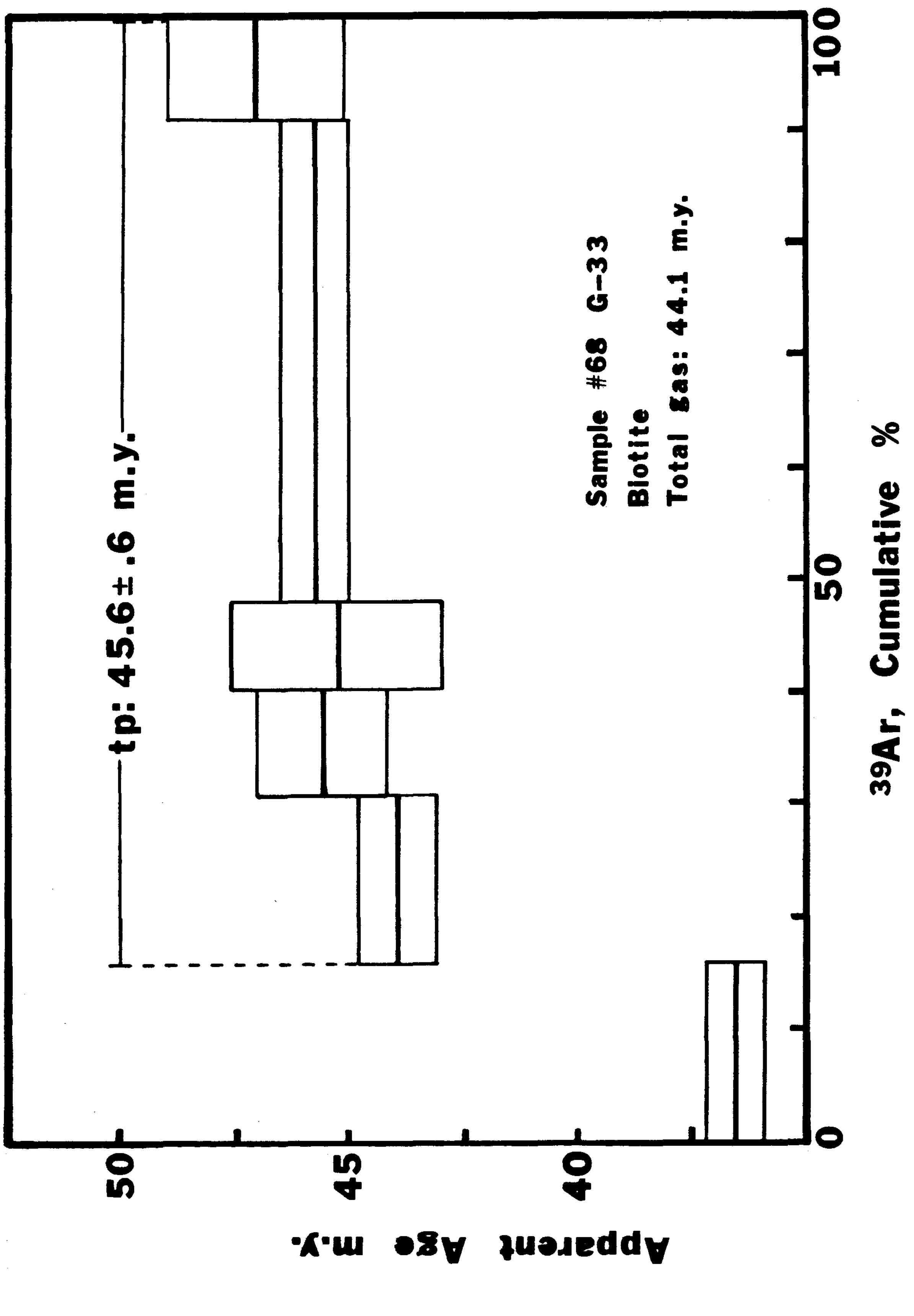

tp: 45.6± .6 m.y.
Sample #68 G-33
Biotite
Total Gas: 44.1 m.y.
0
50
100
39Ar, Cumulative %
50
45
40
Apparent Age m.y.

Figure 5

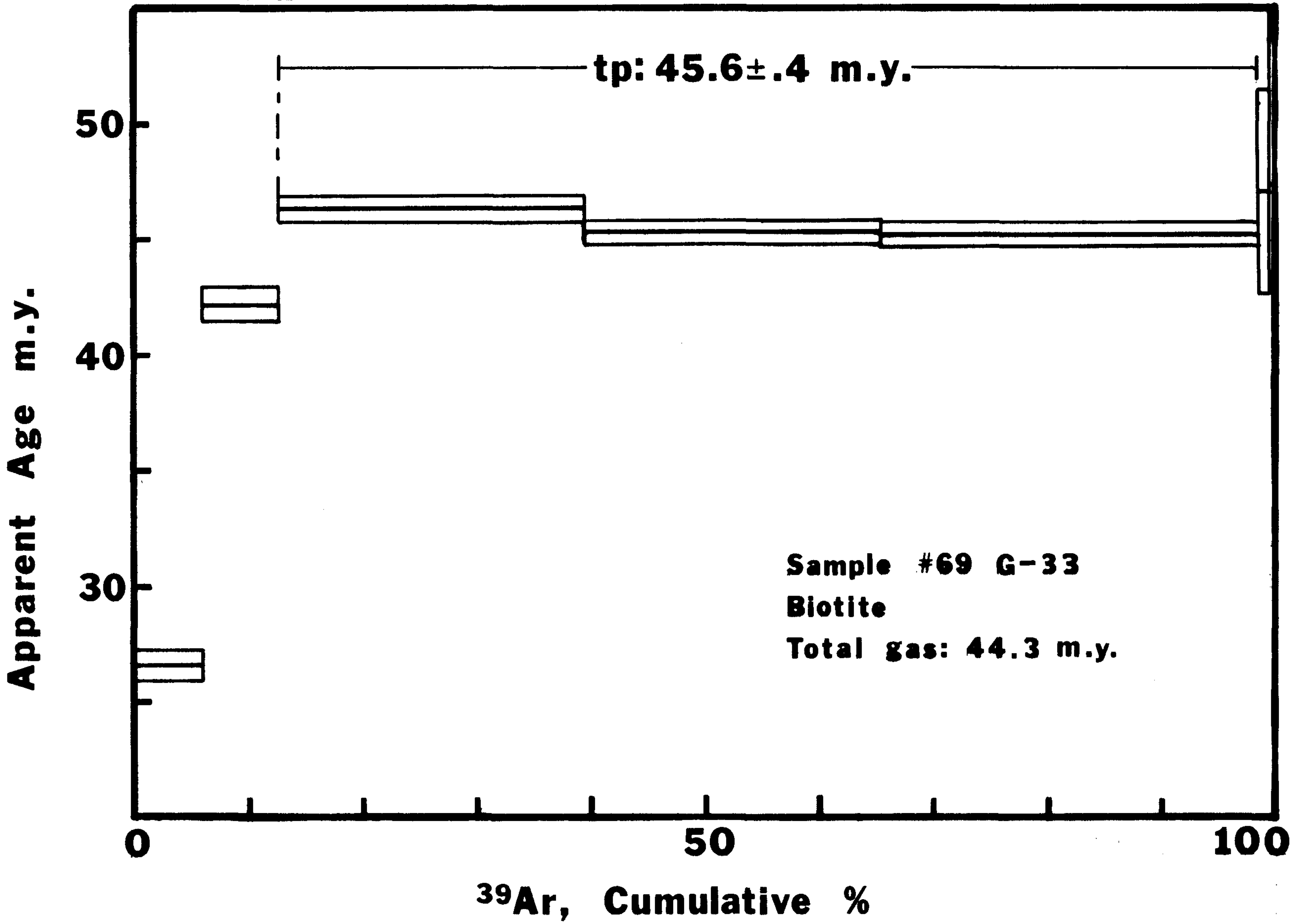

tp: 45.6±.4 m.y.
Sample #69 G-33
Biotite
Total gas: 44.3 m.y.
Apparent Age m.y.
50
40
30
0
50
100
39Ar, Cumulative %

Figure 6

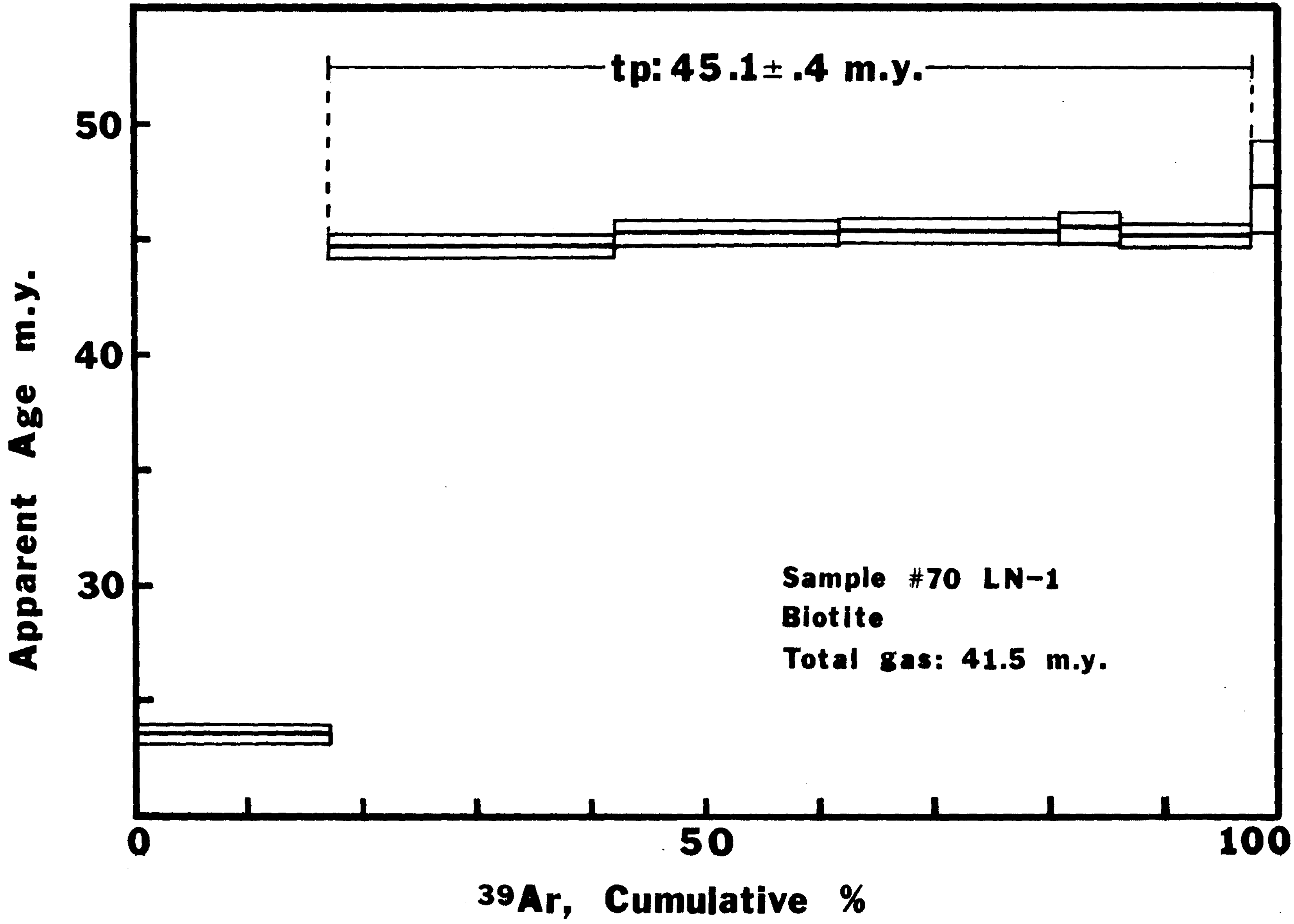
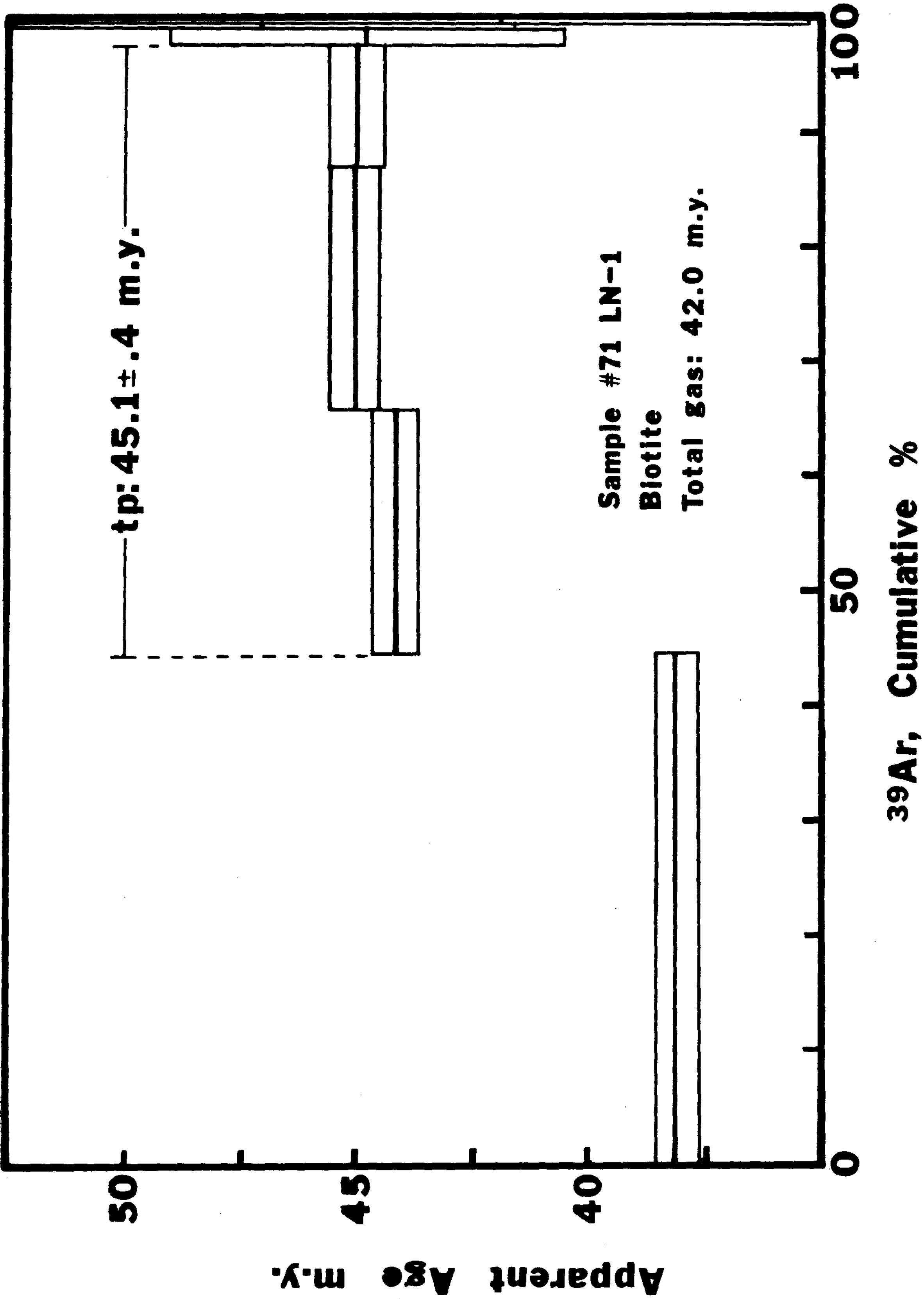

tp: 45.1± .4 m.y.
Apparent Age m.y.
50
40
30
Sample #70 LN-1
Biotite
Total gas: 41.5 m.y.
0
50
100
39Ar, Cumulative %

Figure 7


tp: 45.1±.4 m.y.
Sample #71 LN-1
Biotite
Total gas: 42.0 m.y.
Apparent Age m.y.
50
45
40
0
50
100
^{39}Ar, Cumulative %

should be disregarded, because the remaining fractions follow a fairly close plateau line. These fractions produce an age of 45.6$\pm$ 0.6 m.y. for sample #68. The plateau comprises 84.11% of the ^{39}Ar. The age of the total gas is 44.1 m.y.

For sample #69 (G-33), three fractions along the plateau are suitable for an age. These fractions give an age of 45.6$\pm$ 0.4 m.y. for the sample. The first two fractions do not conform to the plateau and are fairly small. The last two fractions follow relatively close to the plateau, but the % of ^{39}Ar is quite small. The plateau comprises 86.25 % of the total ^{39}Ar. The total gas age of the sample is 44.3 m.y.

All but two of the fractions for sample #70 (LN-1) lie close on the plateau. These fractions give an age of 45.1$\pm$ 0.4 m.y. for the sample. The first fraction contains a fair amount of ^{39}Ar gas (17%), but the age is considerably lower than the plateau line. The last fraction contains a small amount of ^{39}Ar gas and is somewhat higher in age and the plateau. The plateau comprises 80.84% of the ^{39}Ar. The total gas age of sample #70 is 41.5 m.y.

Sample #71 (LN-1) is dated by three fractions on the plateau line that give an age of 45.1$\pm$ 0.4 m.y. The first fraction has 44.7% of the ^{39}Ar gas, but is too far below the plateau. The last three fractions are too small and are not taken into account. The plateau comprises 53.04% of the total ^{39}Ar. The total gas age of the sample is 42.0 m.y.

In summary, G-33 gave ages of 45.6± 0.6 and 45.6± 0.4 m.y.; LN-1 gave ages of 45.1± 0.4 and 45.1± 0.4 m.y. These ages are the same at the one-sigma level.

DISCUSSION

The relative locations and thicknesses of both tuffs in their stratigraphic sections strongly reflect the idea that the tuffs are of the same horizon. Both tuffs are underlain by green mudstone and overlain by 20 cm. units of gray limestone. Also, both tuffs have a similar siliceous rich limestone ledge above them. This ledge is 17 meters above sample G-33 and 16.3 meters above sample LN-1. Most important is the fact that both of the beds that the tuffs were sampled from are 25 cm. thick which is a fairly large size for a tuff bed. The sequence of green mudstone, tuff, and gray limestone is not a distinct feature of the Green River Formation, but the siliceous rich limestone ledge is distinct.

Petrographic studies have shown a close relationship between the two tuffs. Sample LN-1 has 12% biotite, and sample G-33 has 11% biotite. Sample LN-1 has 1% hornblende and 6% altered potassium feldspar while sample G-33 has 5% hornblende and 10% altered potassium feldspar. Sample LN-1 has 7% more matrix (illite) than G-33. Both samples contain about

1% of iron oxide and quartz. The minerals in both tuffs appear well-weathered and highly fragmented. The higher percentage of hornblende in sample G-33 may be traced to the origin of the tuff. Strong winds may of had deposited more hornblende to the sample G-33 location and weaker winds may have lost some of sample LN-1's hornblende upon deposition. According to Sarna-Wojcicki and Waitt (1980) from studies of volcanic ash which erupted from Mount St. Helens, bulk densities calculated from initial uncompacted thicknesses and volumetric (weight per unit area) samples varied systematically downwind: 1.05, 0.74, 0.46, 0.45, and 0.11 g/cm^3. Thus, the distribution of hornblende - the only real difference - may be a contributing factor in the small age variation of the tuffs.

Devitrification of the volcanic glass has formed the clay matrix which is probably mostly illite. Although it cannot be positively proven, the altered potassium feldspar is probably sanidine. The iron oxide forms around the hornblende grains more so than the biotite grains.

The age of sample G-33 is 45.6$\pm$ 0.6 m.y.-45.6$\pm$ 0.4 m.y., and sample LN-1 is 45.1$\pm$ 0.4 m.y. Taking the uncertainties into account, both tuffs fall into the range 45.4$\pm$ 0.3 m.y.

Additional dating of these tuffs would prove valuable in determining the validity of these ages and whether the very small differences are genuine.

Little has been written on the volcanic activity in south central Utah, and even fewer of the volcanic eruptions have been dated. Assuming that approximately 45.4 m.y. ago the winds blew as they now do west to east, the volcanic origin would have had to been west of our location. According to Hintz (no date), ash flows, lava flows, and volcanic breccias formed widespread blankets in western Utah. Volcanic activity centered around the Tintic and Bingham mining districts, around Marysvale, and in southern Utah west of Cedar City. Radiometric dates from these volcanic rocks range from Late Eocene through Early Miocene but cluster in Oligocene time. These tuffs are Eocene in age, and it would be difficult to determine their exact source.

Both tuffs apparently correlate with a tuff collected and dated by Mauger (1977). The tuff Mauger collected is the same as Faulk's (1948) tuff unit #16. Mauger's tuff (RLM-6-71) is located about 19.3 km. from sample LN-1 and 28.9 km. from sample G-33. The tuff was collected at SW$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 14, T. 16 S., R. 3 E. Tuff (RLM-6-71) is 20 cm. thick. Mauger (1977) determined a conventional K-Ar date of 45.8 ± 0.7 m.y., which is within the analytical uncertainty of the dates for LN-1 and G-33. His tuff (RLM-6-71) could very well be the same tuff bed. However, Mauger goes on to say that the sample he dated includes a small percentage of extraneous micas, which may mean his date is too old.

Sheliga (1980) also dated tuffs from this area. Sheliga's (1980) $^{40}Ar/^{39}Ar$ date was 43.3 ± 0.6 m.y. This date is outside the analytical uncertainty of the dates of tuffs LN-1 and G-33; and so, correlation of his tuff beds and the ones studied here cannot be made.

CONCLUSION

The two tuffs seem to be more alike than distinct. Taking into account their similarities in the stratigraphic sections, petrographic studies, and age, it appears that both of these tuffs have a common origin and were deposited at essentially the same time. Arguments may be made due to the slight age difference, but only further dating of the tuffs will verify or deny those arguments. Even though an exact location of the volcanoes which produced the tuffs cannot be pinpointed, it was probably in south-central Utah to the west of the field area.

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